PATENT SPECIFICATION 850,612

DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Improvements in or relating to Prevention of Ice Formation on High Voltage Overhead Transmission Lines.

We, BRITISH INSULATED CALLENDER'S CABLES LIMITED, a British Company, of Norfolk House, Norfolk Street, London, W.C.2, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high voltage overhead transmission lines. In order to reduce the loss and radio interference due to corona bundled conductors are commonly employed, that is to say, instead of a single conductor per phase per circuit of an A.C. transmission line or a single conductor per pole per circuit of a D.C. transmission line, there are two or more conductors which are mutually spaced apart by means of spacers at frequent intervals but are connected electrically in parallel with one another.

Whilst the use of bundled conductor transmission lines is advantageous from the point of view of reducing corona and radio interference and also from the point of view of improving the thermal rating of the line, they are a disadvantage when employed in lines traversing cold and/or mountainous countries in that the risk of trouble due to sleet or ice-formation is greatly increased. With the object of preventing sleet or ice-formation or of melting-off sleet or ice that has already formed it has been suggested to maintain the bundled conductors in spaced relationship by means of insulating spacers and to circulate heating currents through them.

The principal object of the present invention is to provide an improved high voltage over-head line having bundled conductors and means for circulating heating current through a section or sections of the bundled conductors of one or more section lengths thereof without it being necessary to isolate the line from the high voltage source.

In accordance with our invention our improved bundled conductor transmission line comprises one or more than one section in which the component conductors of each bundle are electrically connected together at the ends of the section and between the ends are held in spaced relationship by insulating spacers, means for applying a potential difference between the two conductors (or groups of conductors) of each bundle, and means for preventing the heating current due to the applied potential from flowing round one of the two loops formed by the component conductors of the bundle whilst permitting flow of the high voltage transmission current.

Where the transmission line is a direct current transmission line the means for applying a potential difference between the two component conductors (or groups of conductors) of each bundle is preferably a means for so applying an alternating current and the means for blocking the flow of heating current round the one of the two loops whilst permitting flow of the high voltage transmission current preferably comprises a pair of inductances, one inserted in each component conductor (or in each group of component conductors) of the bundle, between the points of application of the A.C. potential and a point of electrical connection (bundling point) at one end of the section.

Where the transmission line is in alternating current transmission line, the means for applying a potential difference between the two component conductors (or groups of conductors) of the bundle is preferably means for so applying a direct current poten-

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tial and the means for blocking the flow of heating current round the one of the two loops whilst permitting the flow of high voltage transmission current preferably comprises a pair of capacitors, one inserted in series in each component (or in each group of component conductors) of the bundle, between the points of application of the direct current and a point of electrical connection (bundling point) at one end of the section.

In each case it will generally be preferable to apply the potential difference between the two component conductors (or groups of component conductors) of the bundle at a point near to one end of the section and to insert the blocking means between that point and the nearest end of the section. The section itself may extend the full length of the transmission line, or a convenient portion of that length, for example, the portion running at the highest altitudes. It may extend over a single span length or over a number of span lengths.

In applying our invention to a section of a high voltage direct current transmission line employing bundled conductors, except at one or both ends of the section over which it is desired to circulate heating currents, we maintain the component conductors, in the required spaced relationship to one another throughout the section by insulating spacers. At one or both ends of the section the component conductors of the bundle are electrically connected together. At the end of the section remote from the end at which the conductors of the bundle are connected together or, if they are so connected at both ends of the section, at one end of the section, we insert in series in each component conductor of the bundle or in series with each of two groups of the component conductors of the bundle a blocking impedance and connect across the two conductors or two groups of conductors forming the bundle the secondary of a heating current transformer so as to inject circulating current in the closed loop extending from the blocking inductances to the far end of the section. The windings of this transformer are insulated for the full transmission line voltage. The series inductances prevent a virtual short circuiting of the heating current through the adjacent bundle point if any, but readily permit the flow of the high voltage direct current into and out of the section of the line. They also help in smoothing out the harmonics inherent in D.C. transmission systems. Since there is no D.C. potential difference between the two conductors, or groups of conductors, of the bundle the direct current does not flow through the secondary windings of the transformer. Consequently the magnetisation characteristics of the transformer are unaffected and its windings carry only the heating current.

To improve the power factor of the heating current load on the transformer, capacitors may be connected in series or shunt with the heating circuit. The use of such capacitors permits of a reduction being made in the size and cost of the heating transformer required for each section of line.

The invention will be further described with reference, by way of example, to the accompanying diagrammatic drawings, wherein:—

Figure 1 represents the use of the invention with a high voltage direct current transmission line; and

Figure 2 represents the use of the invention with a high voltage alternating current transmission line.

In each of Figures 1 and 2 there are indicated three consecutive sections 1, 2 and 3 of one bundle conductor of the high voltage line. In each section the bundle conductor is represented by two component conductors 4, 5 which, except at the ends of the section, are maintained parallel with, and insulated from, one another by spacer insulators 6 arranged at intervals. Although the component conductors 4, 5 are shown as single lines they may each comprise a group of conductors. At the ends of the sections the conductors are electrically connected together at bundle points 7. Towards one end of each section, the left hand as seen in the drawings, a heating current supply source is connected at the points 8 and 9 to the component conductors 4 and 5 respectively.

In the case of the high voltage direct current transmission line represented in Figure 1, the heating current supply source comprises the secondary winding of a transformer 10, the primary winding of which is fed from a source of alternating current through a switch box 11. The windings of the transformer 10 are insulated for the full transmission line voltage. In each of the component conductors 4 and 5 to the left-hand of the connections 8 and 9 there is inserted an inductance coil 12. The inductance coils 12 prevent a virtual short circuiting of the alternating heating current through the adjacent bundle point 7, but readily permit the flow of the high voltage direct current into and out of the section of the line. The inductance coils 12 will also assist in smoothing out harmonics inherent in D.C. transmission systems. The heating current transformer injects circulating current in the closed loop extending from the connections 8 and 9 to the bundle point 7 at the far (that is the right-hand) end of the section.

There is, of course, no D.C. potential difference between the component conductors 4 and 5, so that direct current does not flow from the transmission line through the secondary winding of the transformer 10. Con-

sequently the magnetisation characteristics are unaffected and its windings carry only the heating current.

To improve the power factor of the heating current load on the transformer, a capacitor 13 is connected across the secondary winding of the transformer 10. Alternately there may be used a capacitor 113 in series with the secondary winding. The use of a capacitor in this way permits of a reduction in the size and cost of the heating transformer 10. In addition, if the series connected capacitor 113 is used it can serve as a limiting reactance to unduly increased current flow in the heating current circuit in the event of a flash over occurring between the spaced component conductors 4 and 5, a circumstance which might arise, for instance, due to the presence of ice on the system and if the heating device is used for de-icing as opposed to the prevention of icing.

In the alternating current high voltage transmission line represented in Figure 2, the system differs from that shown in Figure 1 as follows. The heating current which is fed into the component conductors 4 and 5 is direct current from a rectifier 14 connected between the secondary winding of the transformer 10 and the connections 8 and 9 to the conductors 4 and 5. Also the blocking inductances 12 which were used in the direct current transmission system are replaced by series capacitors 15 which prevent a virtual short circuiting of the D.C. heating current through the adjacent bundling point 7 while permitting the flow of the high voltage alternating current into and out of the section.

The rating of these series capacitors 15 may be so chosen that they also compensate to a desired degree the inductive reactance of the A.C. transmission system, thereby improving the transmitting capacity of the line, and the stability and voltage regulation of the transmission system.

The A.C. power supply for each heating transformer 10 may be obtained from any convenient source of supply ,such as a neighbouring A.C. feeder or distribution cable or transmission line or from an attended or unattended auxiliary generating set. The switch box 11 diagrammatically represents any appropriate means for controlling the supply to the heating transformer.

Provision can be made to switch on or off as required the supply of heating current to the primary of the transformer. This may be effected manually, or switching on or off may be effected automatically as the ambient temperature falls below or rises above freezing point, respectively, or it may be effected by remote control by radio, carrier current or pilot line.

The insulating spacers 6 between the component conductors 4, 5 of each bundle may be made of resin bonded glass fibre, porcelain, glass resin laminates, resin impregnated wood or other suitable insulating material, depending on the voltage to which they are to be subjected. Where the section to which the invention has to be applied is greater than a span length each conductor or each group of conductors of each bundle can be suspended from each supporting mast or tower within the section by separate insulator strings. Alternatively, all the conductors of each bundle may be supported by a single string of insulators, with an insulator inserted between each conductor suspension clamp, or each group of conductor suspension clamps, and the yoke plate from which both clamps, or both groups of clamps, are suspended, in order to provide the necessary insulation between the two conductors, or the two groups of conductors, of the bundle.

The rectifiers used to supply D.C. heating current, as represented in Figure 2, may be of any convenient type, for example mercury pool valves, silicon or germanium rectifiers, or any other appropriate static type of rectifier.

It is assumed that the transmission lines shown in Figures 1 and 2 are continued from the left-hand of the figures as one or more sections similar to the sections 1, 2 and 3. The right-hand end of each figure however represents the end of the line or a connection to a section which has no provision for the circulation of heating current. There is therefore inserted beyond the final bundling point 7 either a series inductance 16 (Figure 1) or a series capacitor 17 (Figure 2) to ensure that the heating current will not flow out of the adjacent section at this position.

WHAT WE CLAIM IS:—

1. A high voltage bundled conductor transmission line comprising one, or more than one, section in which the conductors of each bundle are electrically connected together at the ends of the section and between the ends are in the form of two component conductors or conductor groups held in spaced relationship by insulators, means for applying a potential difference between the component conductors or conductor groups at a position between the ends of the section and means for preventing heating current, due to the applied potential, from flowing round one of the two loops formed by the component conductors or conductor groups on each side of that position whilst permitting the flow of the high voltage current through the section.

2. A direct current high voltage bundled conductor transmission line comprising one, or more than one, section in which the conductors of each bundle are electrically con-

nected together at the ends of the section and between the ends are in the form of two component conductors or conductor groups held in spaced relationship by insulators, means for applying an alternating current potential difference between the component conductors or conductor groups at a position between the ends of the section, and a pair of inductances, inserted one in each component conductor or conductor group on one side of that position, to prevent heating current due to the applied potential from flowing round the loop formed by the conductors on that side whilst permitting the flow of the direct current through the section.

3. An alternating current high voltage bundled conductor transmission line comprising one, or more than one, section in which the conductors of each bundle are electrically connected together at the ends of the section and between the ends are in the form of two component conductors or conductor groups held in spaced relationship by insulators, means for applying a direct current potential difference between the component conductors or conductor groups at a position between the ends of the section, and a pair of capacitors, inserted one in each conductor or conductor group on one side of that position, to prevent heating current due to the applied potential from flowing round the loop formed by the conductors on that side whilst permitting the flow of the alternating current through the section.

4. A high voltage bundled conductor transmission line in accordance with any of the previous claims, in which the point of application of the source of heating current is near to one end of the section and the means for blocking the flow of heating current is inserted between that point and that end.

5. An alternating current high voltage bundled conductor transmission line in accordance with Claim 3, in which the source of heating current is a transformer which supplies the current through a rectifier.

6. A direct current high voltage bundled conductor transmission line in accordance with Claim 2, in which the source of heating current is the secondary winding of a transformer and includes a capacitor for power factor correction.

7. A direct current high voltage bundled conductor transmission line in accordance with Claim 6, in which the capacitor is connected in series with the connection from the transformer to the line.

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PROVISIONAL SPECIFICATION.

Improvements in or relating to Prevention of Ice Formation on High Voltage Overhead Transmission Lines.

We, BRITISH INSULATED CALLENDER'S CABLES LIMITED, a British Company, of Norfolk House, Norfolk Street, London, W.C.2, do hereby declare this invention to be described in the following statement:—

This invention relates to high voltage overhead transmission lines. In order to reduce the loss and radio interference due to corona bundled conductors are commonly employed, that is to say, instead of a single conductor per phase per circuit of an A.C. transmission line or a single conductor per pole per circuit of a D.C. transmission line, there are two or more conductors which are mutually spaced apart by means of spacers at frequent intervals but are connected electrically in parallel with one another.

Whilst the use of bundled conductor transmission lines is advantageous from the point of view of reducing corona and radio interference and also from the point of view of improving the thermal rating of the line, they are a disadvantage when employed in lines traversing cold and/or mountainous countries in that the risk of trouble due to sleet or ice-formation is greatly increased. With the object of preventing sleet or ice-formation or of melting-off sleet or ice that has already formed it has been suggested to maintain the bundled conductors in spaced relationship by means of insulating spacers and to circulate heating currents through them.

The principal object of the present invention is to provide an improved high voltage overhead line having bundled conductors and means for circulating heating current through a section or sections of the bundled conductors of one or more section lengths thereof.

In accordance with our invention our improved bundled conductor transmission line comprises one or more than one section in which the component conductors of each bundle are electrically connected together at the ends of the section and between the ends are held in spaced relationship by insulating spacers,

means for applying a potential difference between the two conductors (or groups of conductors) of each bundle, and means for preventing the heating current due to the applied potential from flowing round one of the two loops formed by the component conductors of the bundle whilst permitting flow of the high voltage transmission current.

Where the transmission line is a direct current transmission line the means for applying a potential difference between the two component conductors (or groups of conductors) of each bundle is preferably a means for so applying an alternating current and the means for blocking the flow of heating current round the one of the two loops whilst permitting flow of the high voltage transmission current preferably comprises a pair of inductances, one inserted in each component conductor (or in each group of component conductors) of the bundle, between the points of application of the A.C. potential and a point of electrical connection (bundling point) at one end of the section.

Where the transmission line is an alternating current transmission line, the means for appplying a potential difference between the two component conductors (or groups of conductors) of the bundle is preferably means for so applying a direct current potential and the means for blocking the flow of heating current round the one of the two loops whilst permitting the flow of high voltage transmission current preferably comprises a pair of capacitors, one inserted in series in each component (or in each group of component conductors) of the bundle, between the points of application of the direct current and a point of electrical connection (bundling point) at one end of the section.

In each case it will generally be preferable to apply the potential difference between the two component conductors (or groups of component conductors) of the bundle at a point near to one end of the section and to insert the blocking means between that point and the nearest end of the section. The section itself may extend the full length of the transmission line, or a convenient portion of that length, for example, the portion running at the highest altitudes. It may extend over a single span length or over a number of span lengths.

In applying our invention to a section of a high voltage direct current transmission line employing bundled conductors, except at one or both ends of the section over which it is desired to circulate heating currents, we maintain the component conductors in the required spaced relationship to one another throughout the section by insulating spacers. At one or both ends of the section the component conductors of the bundle are electrically connected together. At the end of the section remote from the end at which the conductors of the bundle are connected together or, if they are so connected at both ends of the section, at one end of the section, we insert in series in each component conductor of the bundle or in series with each of two groups the component conductors of the bundle a blocking impedance and connect across the two conductors or two groups of conductirs forming the bundle the secondary of a heating current transformer so as to inject circulating current in the closed loop extending from the blocking inductance to the far end of the section. The windings of this transformer are insulated for the full transmission line voltage. The series inductances prevent a virtual short circuiting of the heating current through the adjacent bundle point if any, but readily permit the flow of the high voltage direct current into and out of the section of the line. They also help in smoothing out the harmonics inherent in D.C. transmission systems. Since there is no D.C. potential difference between the two conductors, or groups of conductors, of the bundle the direct current does not flow through the secondary windings of the transformer. Consequently the magnetisation characteristics of the transformer are unaffected and its windings carry only the primary and secondary heating current.

To improve the power factor of the heating current load capacitors may be connected in shunt with the heating circuit. The use of such capacitors permits of a reduction being made in the size and cost of the heating transformer required for each section of line.

The power supply or each heating transformer may be obtained from any convenient source of supply, such as a neighbouring A.C. feeder or distribution cable or transmission line or from an attended or unattended auxiliary generating set.

Provision may be made to switch on or off as required the supply of heating current to the primary of the heating transformer. This may be effected manually or switching on or off may be effected automatically as the ambient temperature falls below or rises above freezing point, respectively, or it may be effected by remote control by radio, carrier current or pilot line.

The insulating spacers between the component conductors of each bundle may be made of resin bonded glass fibre, porcelain, glass resin laminates, resin impregnated wood or other suitable insulating material, depending on the voltage to which they are to be subjected. Where the section to which the invention has to be applied is greater than a span length each conductor or each group of conductors of each bundle can be suspended from each supporting mast or

tower within the section by separate insulator strings. Alternatively, all the conductors of each bundle may be supported by a single string of insulators providing an insulator be inserted between each conductor suspension clamp, or each group of conductor suspension clamps, and the yoke plate from which both clamps, or both groups of clamps, are suspended, in order to provide the necessary insulation between the two conductors, or the two groups of conductors, of the bundle.

In applying our invention to a section of a high voltage alternating current transmission line employing bundle conductors we preferably use the method already described as applied to high voltage direct current transmission line except that we first rectify the current supplied by the heating current transformer before feeding it to the two conductors forming the bundle and that we replace the blocking inductances by series capacitors.

The rectifiers used may be of any convenient type, for example mercury pool valves, germanium rectifiers or any other appropriate static type of rectifier.

The rating of the series capacitors blocking the flow of rectified heating current through a neighbouring bundling point may be so chosen that the capacitors also compensate the inductive reactance of the A.C. transmission system to a desired degree, thereby improving the transmitting capacity of the line, and the stability and voltage regulation of the transmission system.

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FIG. 1.

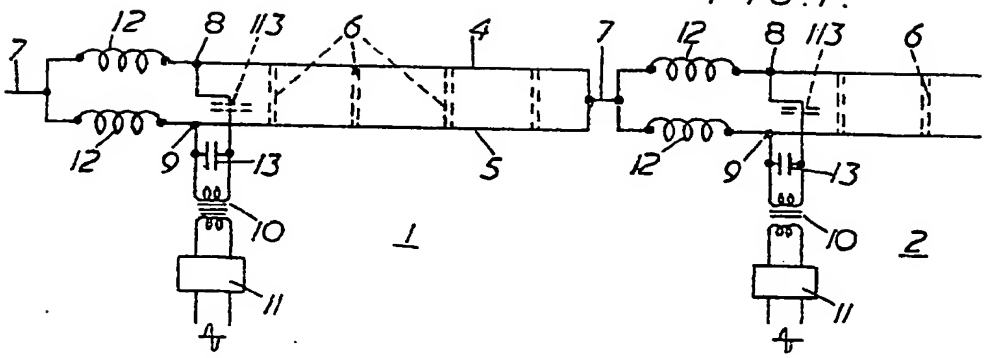
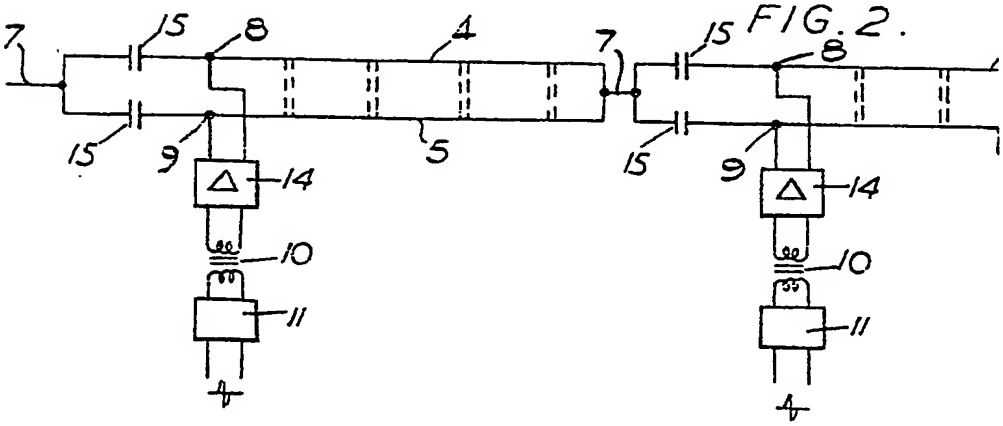


FIG. 2.



850,612 COMPLETE SPECIFICATION

1 SHEET

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FIG. 1.

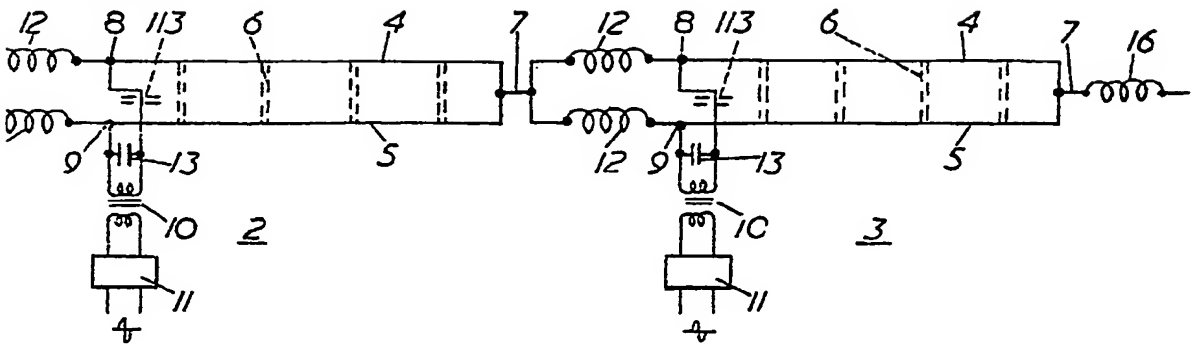

FIG. 2.

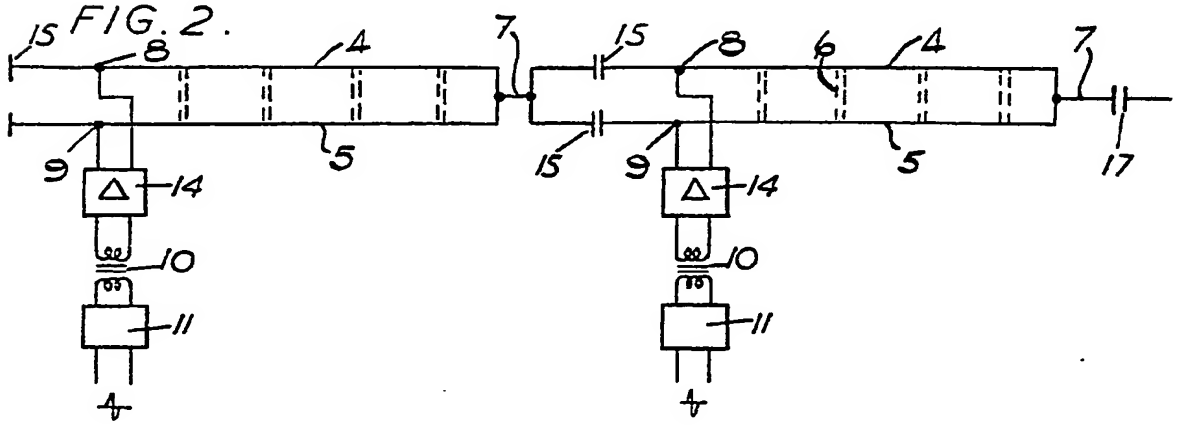

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FIG. 1.

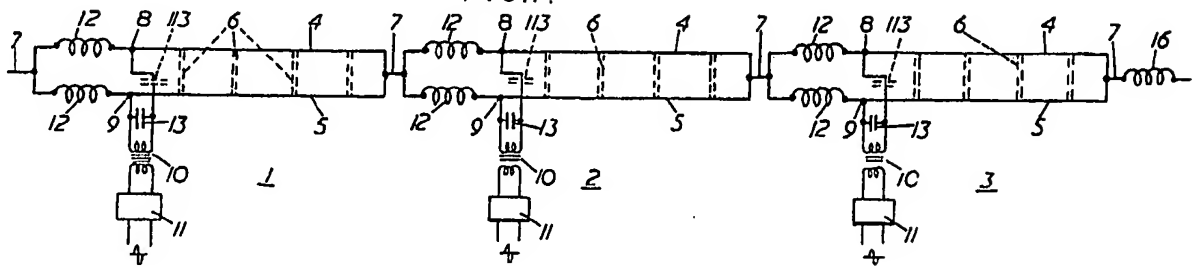

FIG. 2.